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THE EFFECT OF VARIATIONS IN TECHNIQUE ON THE PLATE COUNT OF MILK POWDERS[1]

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Bacteriological plate counts are an important item in grade specifications for milk powders. They are also used in quality control work as an index of plant sanitation and the quality of the raw product. Methods for the bacteriological examination of dried milk products have been recommended, but reports of various workers on the bacteriology of milk powders have indicated some variations in technique and methods. In Standard Methods for the Examination of Dairy Products (1), sterile water at a temperature of 43-49° C. is recommended as the diluent for reconstituting milk powders; but for some types of milk powder that are difficult to get into solution N/10 lithium hydroxide dilution blanks are recommended. Incubation temperatures of 32° C. and 37° C. are both recognized as standard. Prickett and Miller (10) also recommended N/10 lithium hydroxide as a diluent, especially for some types of dried milk products, and found the counts from N/10 lithium hydroxide dilution blanks to compare favourably with counts obtained when sterile water blanks were used. Downs *et al.* (2) recommended N/10 lithium hydroxide dilution blanks for lactic acid dried milks as an aid in dissolving the powders.

Hiscox (5) and Higginbottom (4) used one-quarter strength Ringer solution as the diluent for dried milks, and showed that higher counts were obtained when the temperature of the diluent at reconstitution was at 50° C. rather than at room temperature or approximately 20° C. Both workers also found that a 30° C. incubating temperature gave higher counts than 37° C. for the same incubation period. Speck and Myers (11) showed that reconstituting spray-dried skim-milk cultures of *Lactobacillus bulgaricus* at 37° to 50° C. activated cells that failed to grow when the reconstituting fluid was at 21° to 25° C. In studying the effect of different diluents, Garrison (3) found that dilution blanks of 0.75 per cent of lithium hydroxide or potassium fluoride gave good dispersion of the powders but that both solutions were definitely germicidal. He recommended the use of 1.25 per cent solution of sodium citrate as a diluent and the use of glass beads in the dilution bottle to assist in dispersing the powder.

A study of the effect of variations in the technique of the bacteriological methods used in the examination of various types of Canadian dried milk is reported in this paper. The factors studied were (a) the effect of N/10 lithium hydroxide for reconstitution as compared to distilled water, (b) the temperature of reconstitution, and (c) the temperature of incubation.

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TABLE 1.—COMPARATIVE COUNTS OF MILK POWDERS RECONSTITUTED IN WATER AND N/10 LiOH, AT 37° C. FOR 48 HOURS

Sample No.	Reconstituted in water		Reconstituted in N/10 LiOH	
	at R.T.*	At 50° C.	At R.T.*	At 50° C.
	Spray-dried whole milk			
10565	51,000	72,000	48,000	51,000
10567	136,000	150,000	21,000	20,000
10894	54,000	40,000	550	1,700
11229	150,000	147,000	55,000	43,000
14454	120,000	220,000	3,400	16,700
DG 128	3,100	3,200	170	180
10570	3,100	6,400	640	740
10754	3,100	5,000	930	1,100
13572	600	660	270	290
K 5	490	780	170	330
	Spray-dried skim-milk			
DG 56	1,350	1,860	80	1,550
DG 153	5,100	5,500	3,800	4,100
DG 4	1,200,000	1,500,000	530,000	650,000
13921	160	120	290	80
DG 5	640	730	180	270
	Roller-dried skim-milk			
RRL 8	1,560	1,050	190	110
DG 39	640	250	160	260
DG 102	1,100	1,700	1,200	1,390
DG 103	2,500	2,200	2,300	2,800
DG 120	1,080	1,160	30	120
RRL 210	43,000	21,000	900	5,000
GAS 207	349,000	242,000	126,000	69,000

* Room temperature at 20°-22° C.

METHODS AND MATERIALS

Most of the spray whole milk powders were put up in one-pound tins and sent to the Division laboratory shortly after packaging, by previous arrangement with the manufacturers. Samples of spray skim-milk and roller skim-milk powders were sent in by inspectors of the Dairy Products Division for routine analysis in connection with grading or for check tests.

The powders were reconstituted by weighing 13 grams of whole milk powder or 10 grams of skim-milk powder directly into dilution bottles containing 100 ml. of sterile distilled water or N/10 lithium hydroxide. Reconstitution was made with the diluents at 50° C. and at room temperature (approximately 20-22° C.). When the dried milks were reconstituted with the diluents at room temperature, the dilution bottles were shaken about 25 times and then placed in a water bath at 50° C. to bring the reconstituted milk to this temperature before plating. The dilution bottles were shaken a few times during the heating period and were shaken another 25 times after removal from the water bath. The samples reconstituted at 50° C. were shaken about 50 times and then allowed to stand for about 5 minutes to allow the foam to settle. Not more than 15 minutes elapsed from the time of reconstituting to plating. Further dilutions of the milk reconstituted in N/10 lithium hydroxide were made in sterile distilled water.

Difco tryptone glucose extract agar plus 1 per cent skim-milk was the medium used and the plates were incubated at both 37° C. and 32° C. for 48 hours. Counting was done with a hand lens of the required magnification, and the plates were again examined and counts made using a Spencer binocular giving a magnification of 6×.

Counts are reported as the number per ml. on a reconstituted basis.

RESULTS

No difficulty was experienced in getting spray-dried milks in solution with water, especially when reconstitution was at 50° C. In some cases, roller-dried milks did not completely dissolve in water even at 50° C. and particles of undissolved powder were visible in the plates when counting. Except when pin-point colonies were present, there was no particular difficulty in distinguishing bacterial colonies from undissolved milk particles. When plates were examined with the Spencer binoculars, any undissolved milk particles showed up quite readily. With reconstitution in N/10 lithium hydroxide, all plates were practically free from undissolved powder particles, but frequently the colonies appeared to be somewhat smaller than on plates from water-reconstituted milks.

When skim-milk powders were reconstituted in N/10 lithium hydroxide, it was not uncommon for the milk solids to be practically completely dissolved, producing a watery, yellowish coloured solution which had no resemblance to reconstituted milk.

THE EFFECT OF N/10 LITHIUM HYDROXIDE ON PLATE COUNTS

Typical plate counts, picked at random, for different types of milk powders reconstituted in water and N/10 lithium hydroxide and incubated at 37° C. for 48 hours are given in Table 1. In general, there was a decided

TABLE 2.—DISTRIBUTION OF MAXIMUM COUNTS IN RELATION TO DILUENT AND TEMPERATURE OF RECONSTITUTION

Product	Number of samples	Number of maximum counts			
		Reconstituted in water		Reconstituted in N/10 LiOH	
		At R.T.	At 50° C.	At R.T.	At 50° C.
Incubated at 37° C.					
Spray whole milk	20*	5	14	0	1
Spray whole milk	25**	4	19	1	1
Spray skim-milk	8	2	4	1	1
Roller skim-milk	12	8	2	0	2
Incubated at 32° C.					
Spray whole milk	20*	5	15	0	0
Spray whole milk	29**	8	21	0	0
Spray skim-milk	8	2	4	0	2
Roller skim-milk	11	7	3	1	0

* Samples having counts of 15,000 per ml. or over with water at 50° C. and incubated at 37° C.
** Samples having counts of less than 15,000 per ml. with water at 50° C. and incubated at 37° C.

reduction in the bacterial counts when milk powders were reconstituted in lithium hydroxide even when further dilutions were made in sterile water blanks. In some samples, there was no significant difference, however, especially when the plate counts were relatively low.

The distribution of the maximum counts for individual samples in relation to the diluent and temperature of reconstitution is given in Table 2. These data show that in only a few cases did the maximum count occur when lithium hydroxide was the diluent, and, with the exception of one sample, the maximum count did not exceed 3000 per ml.

For comparative purposes, the plate counts of the samples when reconstituted at 50° C. and incubated at 37° C. were considered as standard and given a value of 100. The relative value for the plate counts for different techniques used were computed on this basis for each sample.

The average percentage counts for all samples are shown in Table 3. The data show that, under the conditions of these analyses, the average values of the counts of the spray-dried whole milks when reconstituted in N/10 lithium hydroxide at 50° C. and incubated at 37° C. were only about 38 per cent of the standard count. When reconstitution was in N/10 lithium hydroxide at room temperature and incubation of the plates at 37° C. the average value of the counts was slightly more than 33 per cent of the standard count.

When incubation was at 32° C., there was the same general trend, and the average counts, with N/10 lithium hydroxide as the diluent, were in about the same percentage relation to the counts from water as when the plates were incubated at 37° C.

Excluding the few samples which had higher counts for lithium hydroxide, the relative values of the counts from lithium hydroxide for the individual samples of spray-dried whole milk powders varied from 4.2 to 97.0 per cent of the standard count when reconstituted at 50° C., and from 1.4 to 78.9 per cent of the standard count when reconstitution was at room temperature.

Lithium hydroxide did not appear to lower the counts of the skim-milk powders as much as with whole milk powders, as indicated by the average relative values shown in Table 3. However, many of the counts for the skim-milk powders were less than 1000 per ml. and the per cent variation from the standard count was often not large.

The relative values of the counts for individual samples of spray-dried skim-milk, which had lower counts when lithium hydroxide was the diluent as compared to water, were from 36.7 to 83.3 per cent of the standard count when lithium hydroxide was used at 50° C., and 4.3 to 72.7 per cent of the standard count when the samples were reconstituted at room temperature. For the roller-dried powders, on the same basis, the counts were 10.3 to 81.8 per cent of the standard for reconstitution at 50° C., and 2.6 to 80.0 per cent of the standard when reconstituted at room temperature. The above comparative values were for counts at 37° C. incubation, but the same general picture holds true for counts at 32° C. incubation.

TABLE 3.—A SUMMARY OF THE AVERAGE PERCENTAGE COUNTS WITH DIFFERENT DILUENTS, AT DIFFERENT TEMPERATURES OF RECONSTITUTION AND INCUBATION

Product	Number of samples	Reconstituted in water		Reconstituted in N/10 LiOH	
		At R.T.	At 50° C.	At R.T.	At 50° C.
Incubated at 37° C.					
Spray whole milk	20*	82.4	100.0	27.2	34.2
Spray whole milk	25**	76.5	100.0	38.3	40.4
Total	45	77.8	100.0	33.4	37.9
Spray skim-milk	8	97.8	100.0	69.2	69.2
Roller skim-milk	11	201.9	100.0	58.8	75.6
Incubated at 32° C.					
Spray whole milk	20*	82.9	124.1	24.6	27.4
Spray whole milk	25**	131.2	180.8	67.5	53.8
Total	45	109.6	155.6	48.5	42.1
Spray skim-milk	8	147.5	104.5	52.6	75.5
Roller skim-milk	10	241.6	159.4	52.0	52.3

* Counts 15,000 per ml. or higher in water at 50° C., incubated at 37° C.
** Counts less than 15,000 per ml.

THE pH OF RECONSTITUTED MILKS

The pH values of a number of samples of reconstituted whole milks in both water and N/10 lithium hydroxide were determined with the Beckman glass electrode pH meter, and are shown in Table 4. Several trials showed that N/10 lithium hydroxide alone had a pH of about 12.2. The average pH value for 13 samples of whole milk reconstituted on the basis of 13 grams of powder to 100 ml. of the diluent was 10.4 for the lithium hydroxide dilution and 6.45 for the samples reconstituted in water. When the reconstituted milk in N/10 lithium hydroxide was diluted 1 : 10 in sterile distilled water there was only a slight decrease in pH, and even when diluted 1 : 100 the average pH was 9.65. Dilution of the water-reconstituted milk raised the pH for both the 1 : 10 and 1 : 100 dilutions to 6.90 and 6.81, respectively.

A number of trials where 1 ml. of 1 : 10 dilution of the reconstituted milks was mixed with 8 ml. of the medium showed very little difference in the pH of the reconstituted milk-medium mixtures, although the use of lithium hydroxide tended to increase the pH slightly when determined colorimetrically with the Hellige comparator and standards. The pH value of the inoculum-medium mixture was about 6.7 when lithium hydroxide was the diluent and only slightly lower for the water-reconstituted milk.

A number of trials were made to determine the effect of the holding period before plating on the counts of powders reconstituted in N/10 lithium hydroxide. After reconstitution at 50° C., the first plates were poured after 5 minutes and additional platings were made at 10-minute intervals up to a holding time of 35 minutes. There was no significant difference in the counts of the individual samples, even after holding for 35 minutes, which would indicate that any bactericidal effect of the lithium hydroxide is almost immediate or at least is effective within 5 minutes.

TABLE 4.—pH VALUES OF RECONSTITUTED WHOLE MILK POWDERS

Sample	Reconstituted in water			Reconstituted in N/10 LiOH		
	Not diluted	1 : 10	1 : 100	Not diluted	1 : 10	1 : 100
10570	6.52	7.00	—	10.30	10.34	—
10571	6.42	6.83	—	10.24	10.02	—
10893	6.45	6.95	6.73	10.16	10.18	9.32
10894	6.35	6.87	6.72	10.22	10.22	9.32
11082	6.35	6.95	7.15	10.12	10.00	9.80
11083	6.34	6.90	6.92	10.08	10.09	8.92
11229	6.38	6.95	—	10.09	9.75	—
11230	6.42	6.95	—	10.09	10.07	—
12336	6.42	6.72	7.15	10.60	10.10	9.80
12337	6.40	6.72	—	10.62	9.98	9.82
K 1	6.57	7.00	6.80	11.01	10.75	9.50
K 2	6.58	6.90	6.78	11.12	10.84	10.25
14383	6.60	7.03	7.22	10.65	10.70	10.12
Average	6.45	6.90	6.81	10.40	10.23	9.65

THE EFFECT OF TEMPERATURE OF RECONSTITUTION

The data show that when whole milk powders were reconstituted at 50° C. the counts were somewhat higher than when reconstituted at room temperature for the majority of samples. With water as the diluent, 34 of 45 samples had higher counts when reconstituted at 50° C. rather than at room temperature for both temperatures of incubation. When lithium hydroxide was used, 30 samples had higher counts when reconstituted at 50° C. with an incubation temperature of 37° C., and 31 samples had higher counts when reconstituted at 50° C. with an incubation temperature of 32° C.

For the relatively few skim-milk powders analysed where counts were in the hundreds for more than half of the samples, the temperature of reconstitution did not show the same effect in increasing the counts. With the skim-milk powders, however, while some counts showed high percentage variations with the different methods of reconstitution and incubation, the counts were so low that there was no practical significance from the standpoint of meeting bacterial standards for grading. The average relative counts for the different types of powder when reconstituted at 50° C. and room temperature are indicated in Table 3.

THE EFFECT OF TEMPERATURE OF INCUBATION

An incubation temperature of 32° C. as compared to 37° C. did not make any significant difference in the counts of whole milk powder as indicated in Table 5. For individual samples, about 50 to 62 per cent showed higher counts at 32° than at 37° C. with the different methods of reconstitution used. However, in the majority of cases, the difference in the counts was so small as to be of no practical significance. The difference in the counts at the two incubation temperatures would have made no change in the grade of the powders if they had been subject to the bacterial standards specified by the Dairy Products Board.

DISCUSSION

In general, bacteria counts of milk powders, both whole and skim, are significantly reduced when N/10 lithium hydroxide is used as the reconstituting medium. This reduction is no doubt due to the high alkalinity or the high concentration of hydroxyl ions in the lithium hydroxide-milk solution. Sommer (12) states that "the sterilizing effectiveness of alkaline solutions is primarily dependent upon the alkalinity of the solution expressed in terms of hydroxyl ion concentration or indirectly in terms of pH".

Other investigators (6, 7, 8, 9, 13), using pure cultures of test organisms or a mixture of organisms from unwashed milk bottles, have shown that alkaline solutions in the pH range of 10.0 to 12.0, and even as low as pH 9.0, destroy a large proportion of the viable organisms in a time period of 1 to 10 minutes. It was also shown that as the alkalinity or pH increased, the time necessary to destroy the organisms decreased.

As N/10 lithium hydroxide alone has a pH over 12.0 and the lithium hydroxide-milk solution has a pH of over 10.0, it is evident that alkalinity is the factor largely responsible for the germicidal effect of the solution on the viable bacteria in milk powders. While N/10 lithium hydroxide does improve the solubility and dispersion of certain types of milk powders and thus eliminates, to a large extent, the inclusion in the plates of undissolved milk powder particles, it is not to be recommended as a diluent for control or routine bacteriological analysis of the usual whole and skim-milk powders.

Reconstituting the milk with the diluent at 50° C. rather than at room temperature increased the counts and helped in putting the powder in solution. Even though the samples after reconstituting at room temperature were heated to 50° C., the counts were not as high as when the diluent was at 50° C. in the first place. This is in accord with the findings of other investigators. Speck and Myers (11) concluded that a reconstituting temperature of 50° C. heat-activated the bacterial cells sufficiently to produce normal growth, as the increase in the colony count could not be accounted for by better solubility of the powder or by a better dispersion of the cells in the reconstituted milks.

In these studies, incubating the plates at 32° C. rather than at 37° C. had less effect on the plate counts of milk powders than either the diluent or the temperature of reconstitution. As both temperatures of incubation are considered to be standard procedure in the United States and Canada,

TABLE 5.—EFFECT OF TEMPERATURE OF INCUBATION ON THE PLATE COUNTS OF WHOLE MILK POWDERS

Method of reconstitution	Average arithmetic counts per ml.	
	At 37° C.	At 32° C.
Water at 50° C.	39,200	41,000
Water at room temperature	29,750	29,690
N/10 LiOH at 50° C.	8,600	8,700
N/10 LiOH at room temperature	6,100	6,000

it will depend on the facilities of the laboratory and the methods outlined under grade specifications as to which temperature should be used. Usually, however, the lower temperature of incubation will allow the highest number of viable organisms to grow under recognized bacteriological methods, and is to be preferred.

The usefulness, from both a control and grading viewpoint, of the bacteriological analysis of milk powders or other dairy products will depend on the effectiveness of the technique in giving the highest estimate of the viable organisms in the product. This is especially true if plate counts are to be used as an index of the sanitation of the equipment and plant. With this in view, these studies indicate that milk powders should be reconstituted in water, or some other diluent that is not bactericidal, at a temperature of approximately 50° C., and the plates should be incubated preferably at a temperature of 32° C.

SUMMARY

The bacteriological analysis of whole milk and skim-milk powders has shown that the use of N/10 lithium hydroxide as a diluent greatly reduces the plate counts. This is probably due to the high alkalinity or pH of the solution. It is not advisable, therefore, to use lithium hydroxide for reconstituting whole or skim-milk powders.

Reconstituting the milk with the diluent at 50° C. increases the plate counts as compared to having the diluent at room temperature.

An incubation temperature of 32° C. as compared to 37° C. had little effect on the plate counts of milk powders under the conditions of this study.

The technique recommended for the bacteriological analysis of milk powders for control or grading purposes is to reconstitute the milk powder in water at a temperature of about 50° C. and to incubate the plates at 32° C. where facilities permit.

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HETEROSIS IN RELATION TO SUNFLOWER BREEDING[1]

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Investigations carried on with sunflowers at the Dominion Forage Crops Laboratory, Saskatoon, since 1936 clearly indicate that further improvement in yield and other important agronomic characteristics will be contingent upon the development of techniques and methods of utilizing heterosis. Although basically similar to the utilization of heterosis in hybrid corn, in sunflowers, because of differences in floral structure and mode of pollination, the techniques of inbreeding and crossing on a large scale will be different. To make a program of hybrid sunflower seed production on a commercial scale successful, satisfactory methods of producing inbred and crossed seed and of selecting and testing for combining ability in the breeding program must be worked out. This paper presents the results of tests of diallel crosses produced by hand pollination and in natural crossing plots and a comparison of methods of testing for combining ability.

LITERATURE REVIEW

The effects of inbreeding and crossing on vigor and yield in sunflowers were noted by Morozov (6) and Jagodkin (2) in Russia. These investigators suggested the production of hybrid sunflowers on a commercial scale. Unrau and White (13) reported a 60.8% increase in seed yield and a much greater uniformity in a hybrid compared to unimproved Mennonite. They observed a positive relationship between high percentage crossing and yield, and attributed a low proportion of crossed seed obtained in natural crossing plots to a lack of simultaneous flowering of the two inbred lines, high self-fertility of the female line or a combination of both factors.

The combining ability of large numbers of inbred lines in corn is usually determined by the use of the top cross using varieties or inbred lines as the testers. This method of testing was developed by Jenkins and Brunson (5). Jenkins in 1935 (4) showed that inbred lines displayed their individuality and desirability as parents of crosses when tested early in the inbreeding program. Sprague and Tatum (9), believe that for testing a large number of inbred lines of corn the top cross should be used for discarding lines having poor general combining ability and that specific combining ability must be determined by diallel crossing of the remaining lines. Sprague (10), found that where a corn variety was used as a tester in a top cross, at least ten plants must be used to give an adequate representation. Tysdal *et al.* (12), have suggested the polycross test in alfalfa to test the combining ability of lines.

MATERIALS AND METHODS

Crossing Studies

In 1943 plants of four inbred Mennonite lines, two introduced Russian lines and the variety Sunrise were reciprocally crossed by hand pollination without emasculation. Two plants of each line were crossed with two plants from every other line. The reciprocal transfer of pollen was

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performed by shaking the pollen of one plant into the paper bag isolator and applying the pollen to the newly opened stigmas of the other plant with a cotton swab. This reciprocal transfer of pollen was performed every second day until flowering was completed. Flowering usually extended over a period of from 7-10 days.

Except for one Mennonite line all possible combinations of the lines listed above were attempted in space isolated natural crossing plots. Where the two lines of a paired combination were known to differ markedly in flowering date, the earlier flowering line was seeded at one or more later dates to obtain simultaneous flowering. The plots were space isolated by distances of half a mile or more. All plots were visited every second day until flowering was completed in order to make the necessary hand crosses and to record flowering dates of each line. Due to uncontrollable factors some plots were failures.

In 1944 seed from the successful reciprocal single-cross combinations produced by hand pollination was used to sow a yield test. In the case of seed from the natural crossing plots, since in 1943 a record was made of the date of flowering of each of the two lines at each date of seeding in each plot and seed from each date of seeding was harvested separately, it was possible to select for the yield test seed from those dates of seeding which had resulted in simultaneous flowering of the two lines in each natural crossing plot. A modified Latin square design with 6 replications and of single row plots was used. The Kemp V-Belt seeder was used in seeding this and test to be described below. Planting was done at a rate to give an approximate spacing of 6 inches between plants in the rows. In both this and the test described below the rows were 36 inches apart. Plots were 20 feet long with the centre 16 feet being harvested for yield determinations.

In 1943 the six lines used in the natural and hand crossing program were also planted in an isolated polycross plot. Each line in the polycross plot was harvested separately. Two plants in each line were hand pollinated with composite pollen from all the other lines. In addition open pollinated seed from the three Mennonite inbred lines used in the polycross plot was obtained from the breeding nursery. This material was tested in 1944 using a simple lattice design in duplicate providing four replications. Size of plots and method of planting were the same as in the previously described test.

In both tests data were obtained on seed yield, plant height, head diameter and flowering date. Seed size was determined by weighing three random 100 seed samples from the seed of each plot and expressing the average on the basis of 1000 seeds. Weight per bushel was obtained by one determination from the seed of each plot. Percentage kernel was determined by the use of a mechanical huller on a 10 gram sample from the seed of each plot. Percentage oil based on the dry weight of the whole seed was determined from a composite sample of seed from all the replicates. The oil analyses were conducted by the Oil Seeds Laboratory, Saskatoon, Sask. Wherever hybrid plants and hybrid seed could be visually distinguished the percentage of hybrid plants and seed from hybrid plants was obtained.

Description of Lines and Varieties

Mennonite is unimproved material, variable for height (usually ranging from 3.5-4.5 feet) for degree of branching, date of flowering and maturity, for seed size and shape and pattern of striping. Seed size varies from 50-75 grams per 1000 kernels with an oil content of between 20 and 28 per cent.

Line A—Strain Number S-37-25-2-1-1-1 is the most vigorous inbred line obtained from Mennonite and has large seed of low oil content.

Line B—S-37-49-2-3-3-1-2 is another inbred line from Mennonite which has shown great uniformity from the third inbred generation onward. It has deep purple pigmentation in leaves, stems and stigmas. The seed when selfed is brown striped but seed from F_1 plants involving this line are solid purple irrespective of the direction of the cross. It is shorter stemmed than Mennonite but has shown some undesirable basal stem weakness. The seed weighs 40-50 grams per 1000 kernels and has an oil content of 30-35 per cent.

Line C—S-37-388-1-1-5-4 is very similar to line B, but lacks the purple pigmentation, is shorter and stronger stemmed and is less vigorous. It has small striped seed of high oil content.

Line D—S-37-402-1-1-3-1-2 is a white seeded inbred Mennonite line taller than the other inbreds and has non-branching strong stems. Oil content is low. Yield of seed is low.

Line E—An extremely early line introduced from Russia under the name "Early Saratov". Extremely low in yield and lacking in uniformity, but of value in a breeding program because of its earliness.

Line F—Released in 1942 under the name Sunrise. This line is the result of four generations of inbreeding from a Russian introduction received in 1937. Sunrise is somewhat shorter and stronger stemmed than Mennonite, has small plump seed with an oil content of usually 30 per cent or over. This line possesses immunity to the sunflower moth, *Homiosoma ellectellum*. According to histological studies by Putt (8), this immunity is due to the presence of an amorphous pigment band between the second and inner seed coat layer. Preliminary studies (7) have indicated this band to be inherited as a simple dominant. To avoid confusion it will be referred to as line F throughout the paper.

Line G—Is another Russian introduction made in 1937 and inbred since then. In all characteristics very similar to line F except that it usually grows 3-4 inches taller and is a few days earlier. The seed, also, is immune to the sunflower moth.

RESULTS AND DISCUSSION

Test of Single Crosses

Yield, Plant Height, and Percentage Crossing

For the sake of brevity only a portion of the data obtained from the 1944 test of hand and naturally pollinated single crosses is presented in Table 1.

As shown in Table 1 highly significant yield differences were obtained among the various single cross combinations. In general the yields obtained appeared to be due to the interaction of percentage crossing and combining ability. On the basis of these two factors, the single crosses can be dealt with in the following four groups:

Group 1. Combinations producing high yield due to the high percentage crossing obtained and to the parents having good combining ability.

Group 2. Combinations producing lower yields due to the intermediate crossing obtained but in which the high proportion of total seed produced by the hybrid plants indicates that the parents possessed good combining ability.

Group 3. Combinations which in spite of a high percentage of crossing produced relatively low yields due to the poor combining ability of the parental lines.

Group 4. Combinations resulting in poor yields due to the low percentage crossing obtained and the low combining ability of the parents.

TABLE 1.—THE YIELD AND OTHER CHARACTERISTICS OF SINGLE CROSSES PRODUCED BY HAND POLLINATIONS AND IN NATURAL CROSSING PLOTS IN 1943 AND TESTED IN 1944

Cross or variety	Yield, lbs. per acre		Plant height (inches)				Per cent hybrid plants in progeny		Per cent of total seed produced by hybrid plants	
	Hand cross	Natural cross	Hand cross		Natural cross		Hand cross	Natural cross	Hand cross	Natural cross
			Hybrid	Self	Hybrid	Self				
B × A	1967	—	42.8	35.1	—	—	65.7	—	87.2	—
A × B	1447	—	41.0	35.5	—	—	28.5	—	64.1	—
F × A	2045	—	47.4	38.3	—	—	64.8	—	94.7	—
A × F	1773	—	45.7	40.2	—	—	79.8	—	95.5	—
C × A	1852	—	46.6	38.5	—	—	69.2	—	—	—
C × G	2005	—	46.9	—	—	—	99.3	—	—	—
G × C	1278	—	44.0	38.1	—	—	29.3	—	—	—
C × B	1935	1705	45.6	41.5	45.8	36.4	59.5	67.2	63.8	—
B × C	1662	1188	42.0	38.4	39.0	—	25.0	—	57.3	—
C × F	1985	1915	44.8	—	47.3	—	98.3	95.8	—	—
F × C	1640	1685	37.3	37.3	45.4	39.8	56.2	46.3	—	—
D × E	1325	1700	39.2	34.3	45.2	40.6	—	72.7	—	85.8
E × D	752	995	37.3	—	40.8	—	—	—	—	—
D × B	—	1757	—	—	47.2	40.0	—	77.7	—	—
B × D	—	1213	—	—	40.3	34.7	—	21.7	—	—
D × F	1743	1798	47.5	41.8	45.0	38.3	74.0	84.0	—	—
C × E	778	1795	39.1	30.5	42.3	38.0	19.2	84.3	—	—
E × C	—	1015	—	—	39.2	33.5	—	—	—	—
A × G	1512	—	47.5	36.2	—	—	40.7	—	74.9	—
G × A	1452	—	45.8	39.2	—	—	42.3	—	83.3	—
C × D	1657	1388	41.2	40.2	41.8	38.8	83.7	92.0	98.2	94.6
D × C	1262	1418	39.8	33.5	44.8	37.4	—	—	—	—
B × E	1098	1610	39.8	30.4	39.6	37.4	31.3	—	60.0	—
E × B	913	1165	38.5	30.0	44.3	33.9	45.8	—	75.7	—
F × E	—	1227	—	—	41.9	37.3	—	—	—	—
E × F	—	768	—	—	39.1	32.0	—	—	—	—
B × G	—	1276	—	—	41.3	34.9	—	60.8	—	—
G × B	—	637	—	—	43.9	41.3	—	20.7	—	—
F × G	1048	825	40.3	—	39.9	—	—	—	—	—
G × F	937	613	41.7	—	40.8	—	—	—	—	—
D × G	—	1500	—	—	45.4	—	—	—	—	—
G × D	—	840	—	—	43.6	41.3	—	—	—	—
Mennonite	1740				47.8					
Line E	773				35.1					
L.S.D.	309				9.0					

On the above basis of grouping, the hand pollinated single crosses B × A, F × A, C × A, C × G, C × B, C × F, D × F and the natural crosses C × B, C × F, D × E, D × B, D × F and C × E would come in the first category where high yields were obtained from a good degree of crossing and good combining ability of the parental lines.

The performance of line C is noteworthy. It was the female parent in seven of the 13 above mentioned combinations. This fact is evidence that it has high general combining ability. In addition in most cases a high degree of crossing was obtained when line C was the female parent. It is apparent, therefore, that line C is a good female parent for use in commercial production of single cross seed. This fact has been utilized in the hybrid variety Advance which was named and licensed in 1945. The variety is a single cross hybrid of C × F.

FIGURE 1. Single Cross G × C. Heterosis is evident indicating good combining ability. Percentage crossing 29.3.

The second group would include crosses such as A × B, B × C, A × G and G × A. These crosses are characterized by intermediate yields, a low percentage of hybrid plants but a high proportion of the total seed being derived from the hybrid plants. This latter fact indicates that either or both parents of these crosses had high combining ability.

In the last two groups low combining ability with or without low crossing was responsible for low yields. The combinations C × D and F × G undoubtedly belong in the third and fourth grouping, respectively. In C × D crossing of 92.0 per cent was obtained, yet the yield was significantly below that of the Mennonite check, indicating that the specific combining ability of these two lines was probably low. Lines F and G are both Russian introductions showing a great deal of morphological similarity, while C and D both have been developed by selective inbreeding from Mennonite. It may well be that in these combinations poor specific combining ability was caused by the presence of similar genes or gene complexes influencing vigor. Results at Minnesota (14), (1) and (3) on corn have indicated that inbreds of diverse genetic origin gave higher yields in crosses than did related ones. Other crosses where poor specific combining ability appeared to be responsible for low yields were E × B and B × G. In the single cross E × B with 45.8 per cent crossing the yield was 913 pounds per acre, only 145 pounds above the yield of inbred line E. The yield of B × G from the natural crossing plot with 60.8 per cent crossing was only 1276 pounds per acre, being significantly lower than that of the Mennonite check. However, lines B and G when used as

parents in combination with other lines have given high yielding single crosses. Thus C × G yielded 2005 pounds per acre, C × B 1935 pounds per acre, B × A 1976 pounds per acre and A × B with 40.7 per cent crossing yielded 1512 pounds per acre. These results clearly indicate that from the standpoint of yield specific combining ability is very important.

In the single cross combinations, where good combining ability existed, marked heterosis was displayed by greater height and plant development of the hybrid as compared to the selfed or sibbed plants. Figure 1 clearly illustrates such a condition. In the single cross F × A yielding 2045 pounds per acre, hybrid plants attained a height of 47.4 inches, while the selfs or sibs averaged only 38.5 inches in height. C × D and G × B are examples where poor combining ability resulted in little heterosis as expressed by yield and height. Thus in the combination C × D the difference between hybrid and selfed or sibbed plants was only 1.0 inches in the hand pollinated cross, and 3.0 inches in the natural cross.

It is significant that, even in the highest yielding single crosses, the height of plants was below that of Mennonite. In addition these single crosses were uniform for this character, making them much more desirable from the standpoint of ease of harvesting. Figures 2 and 3 illustrate the uniformity of the single cross C × F (Advance) as contrasted to Mennonite, for height, stem type and strength, date of flowering and other characters.

With the exception of the cross C × E, there was close agreement between the hand and naturally pollinated combinations in respect to

FIGURE 2.—Single Cross C × F (Advance) from seed from natural crossing plot. Note uniformity for height flowering date, etc.

FIGURE 3. Mennonite. Lack of uniformity for height, stem strength and date of maturity as displayed is undesirable from standpoint of harvesting with a combine.

yield and percentage crossing. This fact is important from the standpoint of testing new inbreds for percentage crossing and combining ability. An illustration of this is found in the results of the hand and natural cross combinations C × F. When produced by hand pollination the cross C × F had 98.3 per cent crossing and yielded 1985 pounds per acre. This same cross produced by natural crossing had 95.8 per cent crossing and yielded 1915 pounds per acre. In the reciprocal the hand pollinations resulted in 56.2 per cent crossing with a yield of seed of 1640 pounds per acre while the same cross produced in a natural crossing plot had 46.3 per cent crossing and yielded 1685 pounds of seed per acre. Hence for this combination similar results were obtained whether hand crossed seed from two plants or naturally crossed seed from many plants was used. The reason for disagreement in the results of the cross C × E when produced by hand as compared to natural crossing was undoubtedly due to lack of homozygosity of line E. Thus the two plants of line E used in the hand pollinations did not give a true picture of the line either as to combining ability or its value as a pollen parent. The results on all the other lines inbred for 3-4 generations indicate that the value of inbred lines as parents in single crosses can be quite adequately determined by reciprocal hand pollinations of two plants of each line.

Providing that flowering of the lines in a natural cross combination occurred simultaneously, percentage crossed seed produced by any line was undoubtedly affected primarily by its degree of self-fertility or the amount of good pollen produced by the other line. Thus the difference obtained

between the reciprocals of the combinations of C with F and C with G can be interpreted as being due to the lower self-fertility of line C, the high self-fertility of lines F and G and the fact that they were good pollen producers.

The single cross C × F produced in natural crossing plots for three successive years has consistently resulted in a high percentage crossing and a high yielding F_1. However, in the reciprocal cross the percentage crossing, and consequently the yield, has been lower. In 1945 the single cross C × F was licensed for commercial production under the name Advance. Obviously only seed from line C of a crossing plot should be distributed unless, after testing, it is found that in certain crossing plots line F produced a sufficiently high percentage of crossed seed to warrant distribution of such seed as Advance.

Among the single crosses listed above another noteworthy feature is that in crosses involving parents having good combining ability in every case percentage crossing of 59.5% or higher resulted in high yields of seed which came mostly from hybrid plants. As pointed out in a previous paper (13), this was undoubtedly due to the greater vigor of the hybrid plants which were able to depress the low yields of the weaker selfs or sibs. In the case of combinations having high combining ability it appears plausible that the effect of lower crossing percentages might be counteracted by increasing the seeding rate so as to have more hybrid plants per unit length of row, and the greater vigor of the hybrids would crowd out or nullify the effect of the selfed or sibbed plants. Tysdal and Kiesselbach (11) present data showing that this phenomenon occurs in alfalfa. However, controlled experiments would be necessary before such a practice could be recommended in commercial hybrid sunflower production.

The natural crossing plots used in this study have had equal numbers of rows of the two parents. In the case of a combination such as C × F, where F is highly self-fertile and a good pollen producer and seed from it cannot be used commercially as it has been grown in the past, it might be possible to use a fairly low proportion of inbred F in a crossing plot and still obtain high percentage crossing unto line C. In that event the total amount of crossed seed produced from a crossing plot would be greatly increased. There is the further possibility that under such conditions the percentage crossing in line F would be higher than if equal numbers of rows of both lines were grown. In addition the proportion of F seed to the total seed produced in such a crossing plot would be low so that the composite might have a high enough percentage crossing to enable distributing all the seed as hybrid seed. Until this is ascertained, it will be necessary to test the seed from line F to determine percentage crossing before its sale or distribution.

Determination of percentage crossing would be facilitated if the line used as the female parent carried a marker gene expressing itself in the seedling stage. Such a character is the purple pigmentation carried by line B. It should be relatively simple to transfer this character to a line such as C by the backcross method using line C as the recurrent parent for 4-5 generations.

Date of Flowering

The flowering dates are summarized in Table 2. Since no differences existed for this character in reciprocals of a combination, only the flowering dates of a cross in one direction are presented.

TABLE 2.—DAYS FROM SEEDING TO FLOWERING OF INBRED LINES AND THEIR SINGLE CROSSES

Line or variety	Number of days from seeding to flowering when						
	Inbred	Crossed with					
		A	B	C	D	E	F
A	85						
B	82	77					
C	84	81	81				
D	85	—	80	76			
E	66	—	71	74	72		
F	87	78	80	82	79	77	
G	85	77	81	79	78	—	83
Mennonite	78						

Since hybrid and selfed or sibbed plants of a single cross were growing in the same rows, a direct comparison between them for this character was possible. With the exception of hybrids involving line E, all single crosses were earlier than either parent. In the cross C × F the hybrids flowered in 82 days, five days earlier than line F and two days ahead of line C. In C × G the hybrids flowering in 79 days were five and six days earlier than line C and G, respectively. It is noteworthy that these two combinations were also in the group having high yield because of high percentage crossing and good combining ability when line C was used as the female parent. The hybrids involving line E had a flowering date intermediate between those of the two parent lines, but in every case closer to that of line E.

It should be mentioned that while in Mennonite the flowering date was earlier than in some of the hybrids, the period over which this process extended was much longer since there is a great lack of uniformity in Mennonite for this character. In the single crosses, on the other hand, the hybrid plants flowered and ripened at the same time and the period in which this process takes place is much shorter so that harvesting would actually not be delayed materially even in crosses flowering later than Mennonite.

Seed Characters

In Table 3 the summarized data on seed characters of some of the single crosses and Mennonite are presented.

Plump seed uniform for shape and of small size was one of the objectives when the project was originally started. The data clearly show that some of the single crosses had seed with very desirable characteristics. To a large degree the original objective had been reached in the single crosses C × G and C × F. Besides producing significantly higher seed yields, they had

TABLE 3.—SEED CHARACTERS OF SOME SINGLE CROSSES AND MENNONITE FROM TEST IN 1944

Cross or variety	Wt. per 1000 seeds (grams)		Wt. per bushel (pounds)		% Kernel		% Oil	
	Hand cross	Natural cross	Hand cross	Natural cross	Hand cross	Natural cross	Hand cross	Natural cross
A × F	61.2	—	29.2	—	51.5	—	30.3	—
F × A	60.5	—	29.0	—	53.4	—	31.7	—
C × G	52.6	—	29.7	—	56.2	—	33.4	—
G × C	52.9	—	29.3	—	56.9	—	33.4	—
C × F	48.1	50.2	29.7	30.3	55.7	56.8	33.4	33.3
F × C	51.4	55.6	29.3	28.8	55.9	55.9	33.4	33.3
D × F	—	52.6	—	26.7	—	50.6	—	30.0
D × E	55.0	—	26.2	—	52.8	—	28.6	—
B × D	—	41.4	—	28.2	—	58.8	—	27.6
Mennonite	63.5		24.9		48.8		27.3	
L.S.D.	5.1		1.8		2.7		—	

an oil content of 6 per cent above that of Mennonite. In addition, since F and G both carry the dominant factor for resistance to sunflower moth damage the seed produced by the hybrid plants of the single crosses C × F and C × G is also resistant. From the standpoint of all characters considered these single crosses, therefore, represent a very material improvement over Mennonite. In Figure 4, seed of lines C and F, the F_1 of C × F and Mennonite are shown.

The desirable seed characteristics of lines F and G were also present in other single crosses involving these lines. While line A was not tested in 1944, in previous years its seed has had an oil content of around 20.0 per cent. The single cross F × A had an oil content of 31.4 per cent, with very desirable seed size and shape. The single crosses D × F D × E and B × D are also interesting from the standpoint of the relationship of oil content of the inbred and the single crosses. Line D, which has low oil content, was present as one of the parents in the three crosses just mentioned. When F was the other parent the oil content was 30.0 per cent, while in the other two the oil content was little above that of Mennonite.

Reciprocal crosses were similar for seed characters as they were for yield, if the percentage crossing was similar. Also, the hand pollinated single crosses produced seed similar to that produced from natural crossing plots provided the lines had been inbred for a sufficient period of time to attain a high degree of homozygosity.

PRELIMINARY STUDIES ON METHODS OF TESTING FOR COMBINING ABILITY

The results of a test on polycross seed of six lines grown in an isolated polycross plot, of seed produced on plants of each of the six lines by hand pollination with composite pollen from the other lines, and of open pollinated seed of the three Mennonite inbred lines from the 1943 breeding nursery, are summarized in Table 4.

TABLE 4.—RESULTS OF THE TEST ON METHODS OF STUDYING COMBINING ABILITY—1944

Line	Method of crossing	Yield (lbs. per acre)	Height (inches)	Head diam. (inches)	Bus. wt. (lbs.)	Wt./1000 seeds, grams	% Kernel	% Oil	Days to flower
C	Poly-cross	1393	43.4	5.2	26.9	47.8	52.0	29.2	75.2
C	Hand cross	1196	40.0	5.0	26.9	43.8	51.0	29.0	79.3
C	Open pol.	1377	38.8	5.0	25.0	54.2	52.0	29.9	76.5
B	Poly-cross	883	38.1	4.9	25.8	42.6	52.0	28.6	79.0
B	Hand cross	862	31.4	5.2	24.9	39.9	58.0	29.8	81.0
B	Open pol.	1270	35.3	5.4	26.5	53.3	49.0	28.7	75.5
D	Poly-cross	1251	41.4	5.3	25.1	49.8	48.0	28.1	77.5
D	Hand cross	1207	41.0	5.4	25.0	49.0	51.0	27.4	80.2
D	Open pol.	1307	39.7	4.9	24.1	56.0	48.0	27.5	77.7
E	Poly-cross	961	38.1	5.6	27.8	56.8	55.0	27.9	66.0
E	Hand cross	1011	38.4	5.0	27.1	49.4	55.0	29.8	74.0
F	Poly-cross	1077	39.6	5.3	26.1	48.4	52.0	27.8	81.2
F	Hand cross	1130	38.9	4.8	26.9	51.0	54.0	28.7	75.8
G	Poly-cross	931	40.0	5.3	27.2	46.8	52.0	27.9	79.5
G	Hand cross	558	38.9	4.9	27.4	37.0	55.0	27.9	80.5
Mennonite check		1014	39.9	4.5	26.4	55.4	49.0	26.0	76.8
L.S.D.		222	5.9	N. Sig.	1.8	6.7	—	—	—

In these studies line C behaved very much as would be expected from the results of single crosses where it gave high yielding single crosses when used as the female with all lines but D. The high yields of line C in this test undoubtedly were due to high percentage crossed seed, regardless of the method used, and to good general combining ability with the pollen parents.

The poor performance of line B is hard to explain. It may be due, in part, to the presence of a fairly large number of plants that had lines E or G as the male parent. The poor specific combining ability with these two lines resulted in low yields in the test of single crosses. It may also be due to the fact that a lower proportion of seed was crossed than in line C in the hand pollinations and the polycross plot. In any case, these studies were inadequate to test the value of this line as a potential parent of single crosses.

From the test of single crosses (Table 1) it was concluded that line D had poor specific combining ability with line C. Furthermore, it was not a parent in any single crosses that gave as high seed yields as when line C was used. On the basis of these studies on methods of testing combining ability lines C and D would be about equal, and the percentage hybrid plants must have been high to have given yields significantly above the Mennonite check.

The results with seed from line E are interesting. Very likely little crossed seed was produced as the result of open pollination in the polycross plot, since it had almost completed flowering when the other lines began. If most plants produced were selfs or sibs, the low yield and extreme

FIGURE 4. A—Seed of Mennonite.
B—Seed of line C.
C—Seed of line F. (Sunrise).
D—Seed of the F_1 of C × F. Note plumpness and uniformity for shape and size. (About $1\frac{1}{4}$ actual size).

earliness would be accounted for. The hand pollinated plants were the later flowering plants in the line. More crossed seed was probably produced and delay in flowering date and higher yield likely were due to the presence of hybrid plants in this treatment. Also, since this line is not uniform the plants used for hand pollinations may have carried genes for lateness.

The results of lines F and G in these studies can be discussed together. Both of these lines are highly self-fertile as was indicated by the low percentage crossing of the various combinations when these lines were used as the female parents. The low yields from these studies, without a knowledge of the self-fertility of these lines, would indicate that they had low general combining ability. However, the test of single crosses showed that the highest yielding single crosses had either F or G as the male parent. Low percentages of crossing in the seed whether produced in the polycross plot or by hand pollination was, undoubtedly, the cause of the depressed yields.

From the single cross test and these latter inadequate studies, it appears that the best method to test inbred lines efficiently for combining ability would be to use two tester strains in a modified top cross. Examples of

two such lines could be C and F. Inbreds having as low self-fertility as line C could be tested as female parents with line G. Those as highly self-fertile and as pollen productive as line F could be tested as male parents with line C. The possibility of using the hand pollination technique in material that has been inbred for 3-4 generations would make such a system quite rapid and efficient provided the testers used have a wide enough range of good general combining ability.

SUMMARY

1. Single crosses significantly outyielding the Mennonite check, and highly uniform for desirable morphological characteristics have been produced by hand pollinations and in natural crossing plots.

2. Single crosses with high percentage of crossed seed and good specific combining ability gave the highest yields. Low yields were caused by poor specific combining ability, low percentages of crossed seed or both of these factors.

3. Good combining ability resulted in marked heterosis of the hybrid plants as manifested by greater height and general plant development.

4. Percentage crossing of 60 or over was adequate to give high yields in crosses the parents of which possessed good combining ability.

5. Testing the possibility of using heavier seeding rates of combinations having good specific combining ability, but crossing percentage below 60 per cent, has been suggested.

6. The minimum amount of line F in a crossing plot of F and C to still give high crossing on to line C should be ascertained.

7. To enable determination of percentage crossing in the F seed from a crossing plot of F and C (Advance) in the seedling stage, it has been suggested to transfer the purple pigment character from line B to C by the backcross method of breeding using line C as the recurrent parent.

8. The data on seed characters further showed the improvement in oil content, plumpness, size and uniformity of shape of the hybrids having lines F or G as one of the parents. These hybrids, in addition, had seed immune to sunflower moth damage.

9. With the exception of hybrids involving line E, all were earlier than either parent entering the cross. When E was one of the parents, the flowering dates were closer to that of line E than to the other parent.

10. The results on yield and seed characters clearly indicated that where lines had been inbred for 3-4 generations, reciprocal hand pollinations using two plants of a line gave reliable information regarding the yield and other characters of a combination.

11. The preliminary studies on methods of testing for combining ability indicated that the use of the polycross would, at best, be limited to the testing of fairly self-sterile lines, and that in these it would be impossible to distinguish those where general combining ability was fairly similar.

12. A method of using two tester lines of good general combining ability is suggested. Fairly self-sterile lines should be tested as female parents with a good pollen producing tester line. Lines as self-fertile as F should be tested as male parents with the self-sterile tester line.

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AN ACCOUNT OF THREE SUCCESSIVE OUTBREAKS OF THE BLACK FLY, *SIMULIUM ARCTICUM*, A SERIOUS LIVESTOCK PEST IN SASKATCHEWAN[1]

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INTRODUCTION

Periodic outbreaks of the black fly, *Simulium arcticum* Mall., have caused serious livestock losses in Saskatchewan during the last few decades. These outbreaks have all centered in the areas adjacent to the South Saskatchewan River from the city of Saskatoon north to where this river meets the north branch. In most cases the greatest losses are sustained in districts some distance, 20-30 miles, from the river, although no doubt every year isolated animals are lost near the river. The severe outbreaks occur at varying intervals, each outbreak apparently depending on a combination of a number of biological and ecological factors. A half-dozen great outbreaks accompanied by sudden and numerous fatalities in livestock have occurred during the last 35 years. Three severe outbreaks occurred in succession in 1944, 1945 and 1946. Since no description of previous outbreaks has appeared in print, the purpose of this paper is to put on record information regarding these outbreaks.

SOME IMPORTANT LIVESTOCK LOSSES DUE TO BLACK FLIES

There are frequent references in the literature to excessive outbreaks of black flies and their effect upon livestock in various parts of the world. Two of the most startling outbreaks in history are those caused by the golubatz fly, *Simulium columbaczense* Schoenbauer, in southeastern Europe in 1923 (3) and 1934 (1). It is claimed that in the former outbreak Roumania alone lost over 16,000 domestic animals, while in the latter over 11,000 were killed in Jugoslavia. This species breeds in the Danube River from which it is borne by the wind for long distances. In the United States (5) severe outbreaks of *S. pecuarum* Riley have occurred in the lower Mississippi Valley with the loss of many animals.

It is well known that black flies are very abundant and annoying throughout the northern areas of Canada. Most of the accounts have dealt with their effect upon man and it appears that very little study has been devoted to their effect upon wild and domestic animals. The only reports of serious livestock losses in Canada known to the authors are from central Saskatchewan. The Rosthern, Duck Lake and Macdowall areas especially have had extensive outbreaks. The first great losses of livestock reported occurred in 1913 when the number of deaths reached the 300 mark. Further heavy losses were experienced in 1919 and again in 1930. Cameron (2) reports heavy swarms of flies in the years 1917 to 1921 but does not report fatalities. Although black flies appear in large numbers every summer no records of importance from 1930 to 1944 are available. In the latter year some $20,000 worth of stock was destroyed

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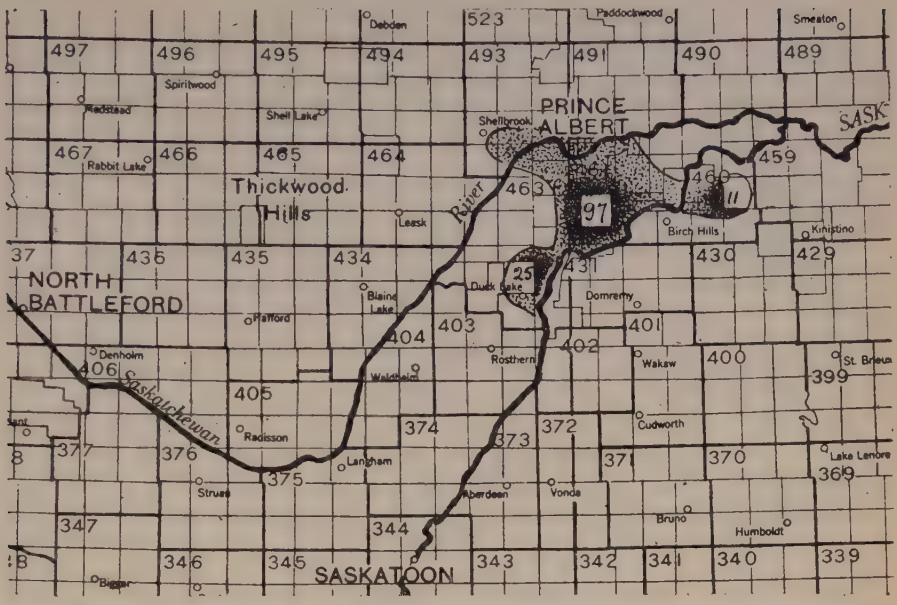

FIGURE 1. Municipal map of the area in which livestock were subjected to severe attacks by *Simulium arcticum* in 1944. Livestock fatalities caused by these attacks occurred in the districts shown by heavy stippling. The figures in white boxes are the number of animals lost. Serious annoyance to livestock was caused in the lightly stippled districts but no fatalities were reported.

in the Macdowall area. In 1945 a minor outbreak occurred in the Prince Albert and Saskatoon districts with an estimated loss of over $5,000. An outbreak of unprecedented proportion in June, 1946, caused a loss of at least 600 head of cattle in two areas. The centres of these districts are located some 50 miles northwest and southeast, respectively from the breeding places with a maximum range of flight of 80-90 miles. Since these extensive losses commonly occur in one day, or at most over a period of several days, and may occur in any area within 100 miles of the breeding places, they have a very disturbing effect on the farming population. This factor should not be neglected when estimating the damage occasioned through black fly attack.

THE 1944 OUTBREAK

The 1944 losses were concentrated in the Macdowall area, some twenty miles southwest of Prince Albert. All losses occurred between May 28 and June 5.

The first area to be invaded was the Weldon-Kinistino district where ten to fifteen animals died as a result of black fly attack. This area is located some twenty miles due east of the main breeding grounds. The main attack occurred in the Red Deer Hill and Macdowall areas on May 31 with the first flies noticed on the previous day. Animals began to die late on May 31 with most dead animals discovered the following morning. Livestock continued to die throughout that day, but few deaths occurred after 3.00 p.m. when the weather turned cloudy and cool. No further fatalities occurred anywhere although a heavy invasion of flies was observed

TABLE 1.—LIVESTOCK LOSSES CAUSED BY BLACK FLIES IN SASKATCHEWAN, 1944

Type of animal	Calves	Yearlings	Cows	Bulls	All cattle	Horses	Sheep	Hogs	Type not recorded	Total
Total number recorded in survey. With few exceptions all bitten	287	225	619	25	1156	301	550	799	—	2806
Total number with various degrees of swelling	2	2	40	1	45	30	20	—	—	95
Per cent affected	0.7	0.9	6.5	4.0	3.9	10.0	3.6	—	—	3.4
Total number dead	1	5	46	7	59	3	11	1	—	74
Per cent dead	0.3	2.2	7.4	28.0	5.1	1.0	2.0	0.1	—	2.6
Additional records of dead animals	—	—	34	2	36	7	5	—	11	59
Total number of recorded dead	1	5	80	9	95	10	16	1	11	133

June 4-6 in the St. Catherines district, twelve miles northwest of Macdowall, and which extended into the Shellbrook area. The districts where losses occurred are shown in Figure 1.

The total number of recorded dead (Table 1) was 133 animals valued at about $20,000. The monetary loss was high because several extremely valuable purebred animals were killed. This record is based on data secured in a survey of the affected farms in the area invaded by the black flies. Although by no means every farmer in the outbreak area was interviewed, the record is believed to include all losses that occurred in all of the affected area. Twenty-seven farmers were interviewed and their replies to a questionnaire recorded. Data for farms not visited were secured from those interviewed and from storekeepers. The accuracy of information supplied by the latter was checked against that given by some of the farmers themselves.

Of the 133 animals recorded as killed, 71 per cent were cattle, 7.5 per cent were horses, 12 per cent were sheep, 1.5 per cent were hogs, the remaining 8 per cent were unclassified. It is significant that 90 per cent of the cattle which died were mature animals, chiefly cows and bulls. Only one calf and five yearlings died. Of the 16 sheep that died ten were sheared adults and six were lambs. Data on the age of other animals were not obtained. Although the average mortality was relatively low (2.6 per cent) losses of livestock were very serious in individual cases. Thus one man lost three extremely valuable purebred bulls and nine purebred cows while another lost all of his herd of four dairy cows.

Investigations of breeding areas and weather records have shown that the flies of this outbreak came from the extensive rapids in the South Saskatchewan River near Fenton.

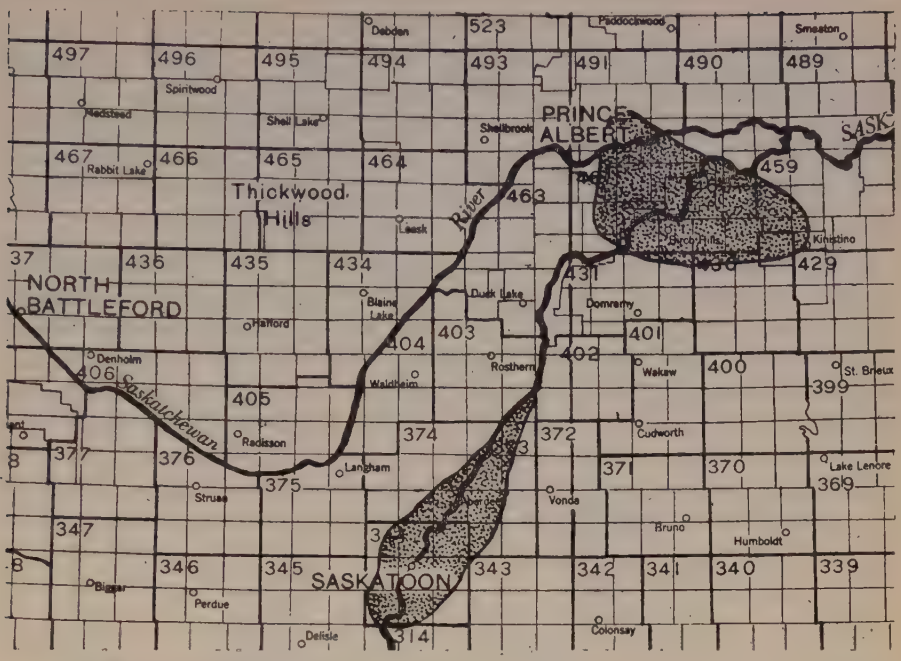

FIGURE 2. Municipal map showing the two districts in which livestock were subjected to severe attacks by *Simulium arcticum* in 1945. Some 50 animals valued at $5000 died in the Prince Albert district, while in the Saskatoon area 20 animals died as a result of these attacks.

THE 1945 OUTBREAK

This outbreak (Figure 2) began at Prince Albert and surrounding areas on Saturday, June 16. The height of the outbreak occurred at 3.00 p.m. on Sunday and flies continued to feed until late that night. Heavy showers fell on Monday over a wide area in the district, and by Tuesday most of the flies had disappeared.

The attack was heaviest in the immediate neighbourhood of the city of Prince Albert. The area under attack, roughly triangular in shape, extended from a point about ten miles directly north of the city south to Red Deer Hill and east to Kinistino. There was nowhere the heavy concentration of flies observed in the previous year at Macdowall.

The actual loss in animals was slight, probably not exceeding a value of $5,000. Weather conditions at the time were such as to distribute the flies over a large area. Moreover, the residents had become aware of the seriousness of these attacks and had taken the necessary precautions (smudges, repellents and sheltering).

Five days later, a very extensive area along the east bank of the South Saskatchewan River in the Saskatoon district was subjected to an invasion. Twenty deaths in cattle were recorded in this area on June 22. Flies here were common for about a month afterwards.

The source of the flies in the northern district was undoubtedly from the Fenton area, but the infestation in the Saskatoon district came from the river at that point.

THE 1946 OUTBREAK

The 1946 outbreak was the most widespread on record and caused the greatest losses so far attributed to black flies in Saskatchewan. Records indicate that in the neighbourhood of 600 animals, valued at $70,000, were lost. If lowered milk production for a period of at least a month and a half throughout the affected area is taken into consideration as well as additional expenditure of labour, the losses might well be doubled.

The first area affected extended from the North Saskatchewan River between Langham and Prince Albert northwest to Shell Lake (Figure 3). Within this region losses were largely confined to an area between Blaine Lake and Shell Lake. All animals were lost on June 2 and June 3, although the flies persisted in the area until June 5 at least. On that day cool weather and rain with a complete reversal in wind direction brought the attack to a close. Since this area had been free of black flies for the entire period of its settlement, the attack came unexpectedly, which accounts for the severe losses (Table 2). However, a rancher stated that in 1912 or 1913 a similar outbreak had occurred causing considerable losses of livestock.

TABLE 2.—LIVESTOCK LOSSES CAUSED BY BLACK FLIES IN SASKATCHEWAN, 1946

District	Calves	Yearlings	Cows	Bulls	All cattle	Horses	Sheep	Hogs	Total
Blaine Lake, Leask, Shell Lake	15	69	199	13	296	4	1	2	303
Meacham, Viscount, Wolverine	7	28	83	18	136	23	—	—	159
Other known	1	—	5	—	6	1	—	—	7
Total recorded all areas	23	97	287	31	438	28	1	2	469
Other estimated	—	—	—	—	—	—	—	—	131
Total definite and estimated	—	—	—	—	—	—	—	—	600

NOTE.—These data were collected at the request of the authors by the Agricultural Representatives of the Saskatchewan Agricultural Representative Service from local Agricultural Improvement Committees.

The 1946 attack was caused by flies borne into the district a distance of 30-60 miles by southeasterly winds on June 2. Two days later the wind changed to the northwest shifting the flight southeast. This flight blanketed the whole area east of the South Saskatchewan from Birch Hills in the north to the Quill Lakes in the east and Kenaston and Outlook in the south (Figure 3). Again the heaviest attack and most of the fatalities were concentrated in an area enclosed by Meacham, Humboldt, Wolverine and Viscount with the centre some 60 miles from the breeding places. The attack was unexpected as residents had never previously experienced one, and within four hours of the first evidence of flies cattle began to die. All fatalities occurred on June 5, but flies persisted for several weeks in most of the area east of the river. Known losses in this area were 159 animals

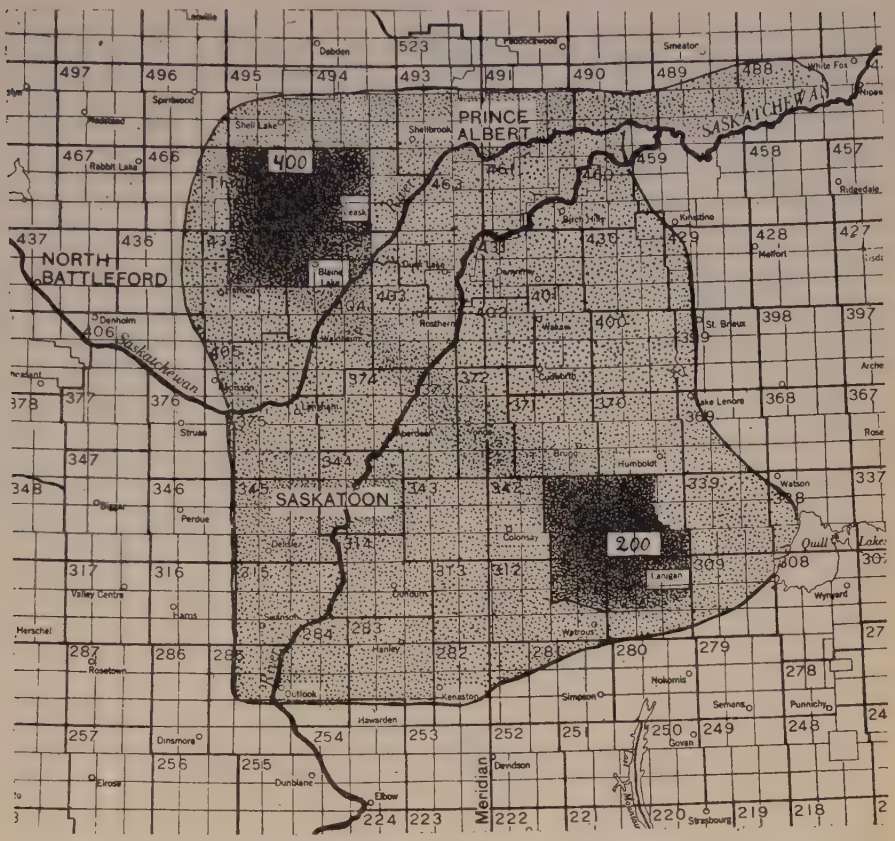

FIGURE 3. Municipal map of the area in which livestock were subject to severe attacks by *Simulium arcticum* in 1946. Districts in which fatalities of livestock resulted are heavily stippled, and the number of animals lost is shown by the figures in white boxes.

with an estimated total of 200 (Table 2). Beginning June 8 severe annoyance to livestock, but no deaths, also occurred in a narrow area west of the river from Saskatoon to Conquest.

The 1946 losses bear close resemblance in all essentials to those in the 1944 outbreak. Again most of the animals lost were cattle, *i.e.*, 93.4 per cent, and only 6.6 per cent were horses. In addition one sheep and two hogs were reported to have died. All animals that were killed died within a day of the first attack, and many within a few hours. Those that survived this period recovered fully. As in 1944 there was a very noticeable variation in individual susceptibility. Some heavily bitten animals showed few signs of discomfort while others, apparently relatively lightly attacked, died.

The noteworthy features of the 1946 outbreak were, *first*, the complete absence of mortality in a strip of about 30 miles wide on either side of the South Saskatchewan River; *second*, the heavy losses in two large areas with their centres removed some 60 miles from the main breeding places; *third*, that some flies were borne for a distance of close to 100 miles; *fourth*, the very large total area involved.

TABLE 3.—WEATHER RECORD, PRINCE ALBERT, SASKATCHEWAN, MAY 25-31, 1944

Date	May 25			May 26			May 27			May 28			May 29			May 30			May 31		
Time	Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind	
		V	D		V	D		V	D		V	D		V	D		V	D		V	D
A.M.																					
12:30	45	2	SE	53	7	W	56	3	WSW	60	C		64	C		50	2	NW	64	10	E
1:30	45	3	WNW	51	6	W	55	3	W	57	C		59	3	S	48	2	NW	64	14	E
2:30	45	5	W	50	6	W	52	2	W	55	C		56	2	SE	53	C		60	20	E
3:30	45	10	NW	47	5	W	51	2	SW	52	C		54	2	S	55	C		59	20	E
4:30	45	10	N	41	2	W	51	2	W	50	2	SE	54	3	S	56	C		58	13	E
5:30	46	8	WNW	45	3	W	50	2	W	51	2	S	54	2	W	55	C		58	10	E
6:30	47	4	WNW	47	4	W	54	2	W	60	5	SW	56	3	NW	56	C		56	16	E
7:30	50	8	WNW	54	3	WSW	61	2	W	66	2	SW	68	11	NNW	62	2	E	58	15	E
8:30	48	C		61	5	W	66	C		70	5	SW	72	14	NNW	67	15	NE	61	20	E
9:30	48	5	W	65	10	W	72	C		74	15	SW	75	20	NNW	68	14	E	63	15	ESE
10:30	54	5	W	70	15	W	76	C		79	10	SW	75	15	NW	70	14	E	64	15	ESE
11:30	60	10	NW	72	15	WNW	78	C		82	15	SW	78	15	NW	72	14	ENE	65	15	ESE
P.M.																					
12:30	63	20	NNW	73	15	W	79	C		83	15	WSW	78	15	NW	74	11	E	64	14	ESE
1:30	64	21	NW	75	18	W	82	5	S	85	20	SW	79	24	WNW	76	14	E	68	11	E
2:30	65	15	N	75	20	W	83	2	W	86	15	SW	81	20	NW	77	20	E	74	25	ESE
3:30	67	20	N	77	20	WSW	83	4	SW	86	14	S	81	13	NW	78	20	ENE	75	25	E
4:30	61	13	NW				84	2	SW	85	10	S	81	25	NW	75	20	E	78	25	ESE
5:30	64	30	NW	76	15	W	84	C		84	10	S	80	20	NW	76	20	E	75	25	E
6:30	60	10	NW	75	25	W	84	C		82	5	SW	79	15	WNW	76	20	E	74	25	E
7:30	60	10	NW	73	25	W	82	C		81	5	SW	77	10	NNW	75	15	E	71	20	ESE
8:30	61	3	NW	71	10	W	80	C		79	5	S	75	5	NNW	73	10	E	69	20	ESE
9:30	56	5	NW	70	10	NW	75	C		74	10	S	67	C		68	15	E	67	20	ESE
10:30	54	5	NW	62	6	W	63	C		72	5	SW	58	C		66	15	E	65	20	ESE
11:30	53	5	NW	59	6	W	61	C		69	10	SSW	56	C		65	15	E	62	25	ESE

V = Velocity. D = Direction of wind. Temp. = Temperature in degrees Fahrenheit.

TABLE 3.—*Continued*—WEATHER RECORD, PRINCE ALBERT, SASKATCHEWAN, JUNE 1-6, 1944

Date	June 1			June 2			June 3			June 4			June 5			June 6		
Time	Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind		Temp.	Wind	
		V	D		V	D		V	D		V	D		V	D		V	D
A.M.																		
12:30	61	30	ESE	49	20	E	37	25	E	44	20	ENE	48	3	E	50	3	WNW
1:30	60	30	ESE	49	20	E	37	25	E	43	20	ENE	44	C		46	C	
2:30	60	28	ESE	48	25	E	37	25	E	43	20	ENE	43	C		46	C	
3:30	56	15	ESE	48	20	E	38	27	E	42	20	ENE	44	C		45	C	
4:30	53	20	ESE	46	20	E	38	20	E	40	20	ENE	39	5	NE	44	C	
5:30	52	15	ESE	44	25	E	38	20	E	39	20	NE	38	C		42	C	
6:30	52	20	ESE	44	25	E	37	20	E	40	20	NE	40	C		45	C	
7:30	54	15	ESE	44	20	E	37	20	E	43	25	ENE	47	C		49	C	
8:30	50	15	E	45	20	E	38	25	E	44	20	E	55	6	NNW	59	C	
9:30	52	20	E	45	24	E	37	24	E	49	26	NE	59	11	N	67	2	NNW
10:30	51	15	ESE	45	22	ESE	37	25	ENE	52	30	E	60	6	ENE	70	5	NW
11:30	50	17	E	46	18	E	37	25	E	50	24	E	61	12	NNE	72	11	NW
P.M.																		
12:30	50	16	E	46	24	E	37	18	ENE	56	18	E	62	15	N	71	14	NW
1:30	49	14	E	47	22	E	37	27	E	60	24	E	64	7	NNE	74	10	NNW
2:30	50	15	E	47	20	E	37	22	ENE	60	28	E	66	14	NNE	74	15	N
3:30	50	17	E	46	25	E	37	14	E	62	24	E	66	7	N	76	12	N
4:30	51	20	E	46	28	E	41	10	E	63	23	ENE	67	15	NE	74	10	NE
5:30	51	15	E	44	30	E	43	15	E	61	24	NE	68	5	N	75	5	N
6:30	51	16	E	43	29	E	45	15	E	61	30	ENE	68	7	NW	74	4	NE
7:30	51	15	ESE	43	25	E	47	15	E	60	25	E	67	9	NNW	72	2	E
8:30	50	15	ESE	40	25	E	47	10	E	57	18	E	64	2	NW	71	C	
9:30	50	10	ESE	39	23	E	46	7	E	54	10	NE	58	C		63	C	
10:30	50	15	E	38	25	E	46	15	E	51	5	NE	52	5	W	57	C	
11:30	49	20	E	38	25	E	45	15	NE	48	3	ESE	51	3	WNW	53	5	ENE

V = Velocity. D = Direction of wind. Temp. = Temperature in degrees Fahrenheit.

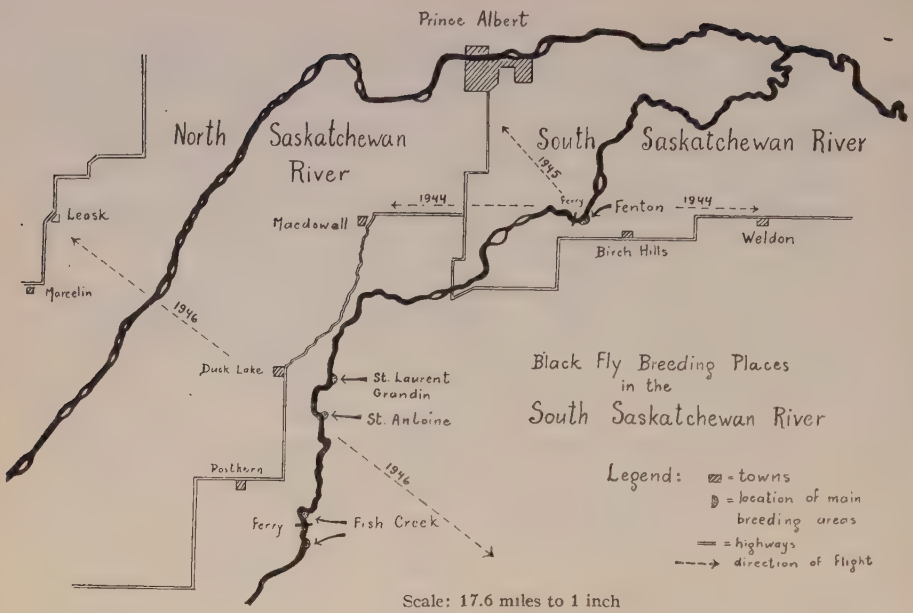

FIGURE 4. Map of the North and South Saskatchewan Rivers showing the location of extensive known breeding grounds of *Simulium arcticum* which produced the mass outbreaks of flies in 1944 to 1946.

BREEDING PLACES

It is an established fact that *Simulium arcticum* breeds in the rapids of the South Saskatchewan River. Investigations made by Cameron (2) in the years 1917-1922 and by the authors in the last three years have disclosed that the mass emergences of black flies have taken place from the rocky beds in this river. Such rocky beds are rather extensive in the South Saskatchewan from Saskatoon to the junction (Figure 4) but quite rare in the North Saskatchewan above Prince Albert. The latter has a deep bed in which the river meanders between islands, sand bars and mud flats (Figure 5). The South Saskatchewan, on the other hand, has a shallow river bed with an even shore line in which islands and mud flats are rare (Figure 6). In many localities of the latter below Saskatoon, the shore and the floor of the river bed are gravelly and rocky. In such places black flies have been found to breed in large numbers. Investigations during the last three years have disclosed that the main breeding areas are found in this river from Saskatoon to the junction with the north branch. These areas are indicated by Figures 4 and 7. They are briefly described below.

Fish Creek. A very extensive rocky bed along the east bank is found two and one-half miles south of the town. It extends diagonally downstream with rapids at any water level. A second bed is found immediately north of the ferry. Here the east shore is rocky for a distance of one-third of a mile and a stony arm extends diagonally downstream (Figure 7). This bed is known to breed black flies in large numbers.

St. Antoine. This is a very extensive rocky bed which projects diagonally upstream raising the level of the water along the east bank and causing it to fall swiftly over the rocks (Figure 7). There are rapids here at all levels of the river.

St. Laurent Grandin. The river here has an extensive rocky shore along the east bank and several stony islands. Rapids are present on either side of an island in mid-stream.

Fenton. One mile north of Fenton ferry is a large stony bed running parallel to the shore for a distance of about 300 yards. At low water level the bed is connected with the east bank. The river strikes the east bank, then swings sharply toward the west shore. Rapids extend almost completely across the river. At high water level the river flows over the main bed causing further rapids near the east shore (Figure 7). Other rocky beds are to be found in this general area.

Saskatoon. A minor rocky bed is found one mile north of the city. It is connected with the east shore with rapids at any water level.

Although, no doubt, other breeding areas are found in the river, it is felt that the above are to be looked upon as the main ones. There appear to be no important breeding places in the river above Saskatoon. Our findings suggest that the outbreaks of 1944 and 1945 were caused by flights coming from the Fenton district, while the 1946 outbreak was the result of mass emergence at Fish Creek and St. Antoine. There are no small streams in the areas involved which are suitable for mass breeding of *simulium articum.*

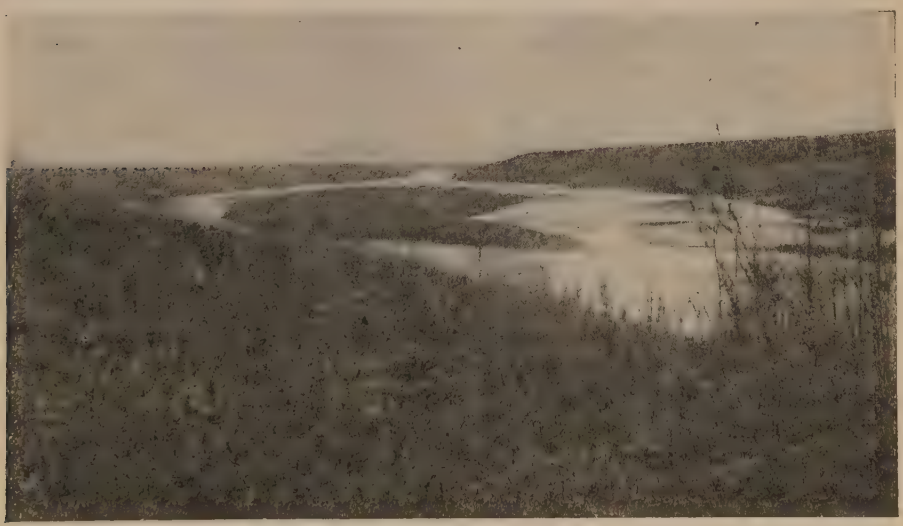

FIGURE 5. View of the North Saskatchewan River at Wingard at low water level. Note the wide deep valley, the large island, and the extensive sand and mud flats. Note also the absence of rocks, gravel or rapids. This view is typical of the North Saskatchewan from Hepburn to Prince Albert. There are few, if any, places in this part of the river suitable for black fly breeding.

TABLE 4.—WEATHER RECORD, PRINCE ALBERT, SASKATCHEWAN, JUNE 15-17, 1945

Date	June 15			June 16			June 17		
Time	Temp.	Wind		Temp.	Wind		Temp.	Wind	
		V	D		V	D		V	D
A.M.									
12:30	48	C		51	4	SE	54	6	SW
1:30	46	C		45	1	SE	52	6	WSW
2:30	50	2	W	41	C		53	10	W
3:30	56	C		40	4	E	54	5	W
4:30	51	3	W	40	1	E	51	10	W
5:30	46	7	NW	40	1	E	51	5	W
6:30	46	C		44	C		49	7	WNW
7:30	59	C		53	C		55	4	W
8:30	61	3	N	58	C		60	5	W
9:30	65	C		63	C		65	5	W
10:30	66	4	N	65	C		67	10	W
11:30	66	C		65	C		70	4	WNW
P.M.									
12:30	67	9	E	66	C		72	18	NW
1:30	67	15	NE	68	4	SW	72	11	NW
2:30	65	6	N	70	C		74	20	NW
3:30	68	12	NE	70	C		73	10	NW
4:30	67	10	NE	69	C		73	10	WNW
5:30	69	3	E	69	C		72	16	NW
6:30	66	16	ESE	69	C		68	12	WNW
7:30	62	11	SE	67	15	SE	66	18	N
8:30	61	2	SE	63	7	SE	63	6	N
9:30	55	C		59	10	SSE	59	4	N
10:30	52	C		56	8	S	57	2	N
11:30	52	6	E	53	C		56	1	N

V = Velocity. D = Direction of wind. Temp. = Temperature in degrees Fahrenheit.

METHOD OF DISPERSAL

It is a well established fact that this black fly is readily carried by wind for considerable distances. Cameron (2) describes a migration of black flies from the South Saskatchewan River for a distance of at least 12 miles in a northwesterly direction on June 14, 1918. This migration took place during a strong southeast wind. Cameron believes that "there can be little doubt but that the wind is the chief agent in the dissemination of the adults". According to Baranov (1) the golubatz fly is borne as far as 90 miles from its breeding areas.

In the spring of 1944 a search for the breeding places of black flies immediately following the great outbreak was not successful owing to the sharp rise in the level of the river after June 1. However, further search in August revealed that very extensive black fly breeding had taken place recently near Fenton ferry, there being countless pupal cocoons on the stones in a fine state of preservation. That this area was largely, if not exclusively, responsible in that year for the mass emergence of black flies is readily seen from the fact that both the Weldon and the Macdowall

FIGURE 6. Typical view of the South Saskatchewan River below Saskatoon. Note the narrow, shallow valley, the regular shore line, and the absence of large islands and mud flats. At irregular intervals in this river extensive rocky beds form rapids in which black flies breed in tremendous numbers.

attacks could be traced to this area. Weldon is located due east of Fenton, Macdowall due west (Figure 4). The Weldon attack which occurred in the afternoon of May 26 followed a strong west wind (Table 3), while the Macdowall attack on May 31 followed a wind from due east. No other breeding grounds are so situated that they could have contributed to this outbreak.

That the rapids at Fenton contributed also to the 1945 outbreak at Prince Albert is shown by the meteorological data for that period (Table 4). The heavy attack on June 16 followed a predominantly southeast wind on the evening of the previous day. Further, the direction of the wind on June 17 explains the presence of flies in the Kinistino area the following day.

The 1946 outbreak at Leask and Shell Lake on June 2 followed in the wake of a steady southeast wind on that and the previous day. The outbreak in the Viscount-Guernsey area on June 5 followed a steady northwest wind (Table 5). A direct line connecting Shell Lake, Leask, Viscount and Guernsey reflects the direction of the winds of these days and also indicates the breeding areas to be Fish Creek and St. Antoine (Figure 4). Although this evidence is circumstantial only, it is supported by the fact that a survey failed to disclose any likely breeding areas in the North Saskatchewan. It has already been pointed out that the latter river is a muddy shallow stream that meanders through numerous islands, sand bars and mud flats. At no place have we found here rocky beds that are comparable to those in the south branch. Finally, it is known that the rocky beds at Fish Creek are productive areas (2).

Owing to the fact that black flies are borne by the wind for long distances it would seem that most of these flies never get back to the main breeding areas for oviposition and that "restocking" is largely done by those flies

TABLE 5.—WEATHER RECORD, SASKATOON, SASKATCHEWAN, JUNE 1-5, 1946

Date	June 1		June 2		June 3		June 4		June 5	
Time	Wind		Wind		Wind		Wind		Wind	
	V	D	V	D	V	D	V	D	V	D
A.M.										
2:00	9	SW	13	SE	17	SE	13	SW	6	NW
3:00	9	SW	11	SE	14	SE	13	SW	2	NW
4:00	12	SW	10	SE	14	SE	12	SW	3	NW
5:00	12	SW	10	SE	17	SE	4	NW	1	NW
6:00	13	SW	11	SE	16	SE	3	W	C	
7:00	13	SW	13	SE	14	SE	7	W	C	
8:00	16	SW	16	SE	18	S	18	NW	C	
9:00	15	SE	17	SE	22	S	20	NW	C	
10:00	14	SE	20	SE	22	S	24	NW	2	NW
11:00	14	SE	19	SE	26	S	22	NW	5	NW
12:00	16	SE	20	SE	24	SW	24	NW	6	NW
P.M.										
1:00	15	SE	21	SE	24	S	23	NW	5	N
2:00	15	SE	18	SE	20	S	22	NW	6	NE
3:00	16	SE	16	SE	21	SE	21	NW	4	N
4:00	16	SE	18	SE	20	SE	19	NW	5	NE
5:00	16	SE	19	SE	21	SE	18	NW	4	NE
6:00	12	SE	16	SE	21	SE	19	NW	6	NE
7:00	13	SE	15	SE	25	SE	17	NW	10	NE
8:00	9	SE	14	SE	21	SE	16	NW	9	E
9:00	5	SE	13	SE	20	SE	12	NW	9	E
10:00	8	SE	14	SE	22	SE	10	NW	8	E
11:00	13	SE	11	SE	19	SE	10	NW	11	E
12:00	14	SE	15	SE	18	SE	9	NW	8	E
A.M.										
1:00	13	SE	16	SE	10	SE	8	NW	4	NE

V = Velocity. D = Direction of wind.

that can be seen throughout the summer in areas close to the river. Such a situation would help to explain the sporadic occurrence of excessive outbreaks.

These sporadic mass outbreaks of black flies no doubt are dependent upon a number of biological and ecological factors which await future study.

FEEDING HABITS OF *SIMULIUM ARCTICUM* AND THEIR EFFECT ON THE HOST

Feeding Habits. The female of this black fly is a vicious biter of livestock, especially older cattle and horses. The flies commonly congregate on the less hairy portions of the animal body, such as the undersurface of the belly, the inguinal region particularly in front of the udder in cows and on the scrotum of bulls, just behind the front legs and on the neck region. They do not attack the animal to any extent in the facial region. Large numbers of flies will alight on the animal and often "run" over the skin until a less hairy area is found. Once the mouth parts are inserted, the fly is not readily disturbed. Black flies have short mouth parts, which possibly explains their predilection for the bare regions.

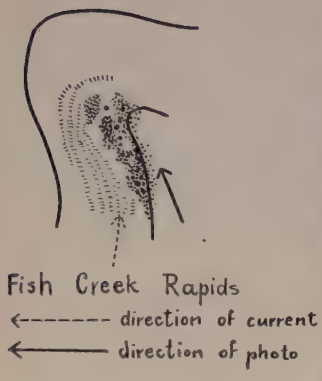

FIGURE 7. Photographs taken at low water level of three important breeding places of *Simulium arcticum* in the South Saskatchewan River. Note the rapids and the extensive rocky beds. In the spring these rocks are under water and are then teeming with black fly larvae.

The authors' observations indicate that this black fly feeds predominantly during daylight hours. The flies are most active on hot sunny days. During cool cloudy weather few are noticed. When the weather becomes clear and warm, they come out again in large numbers. It is not known whether the species feeds at night. Some farmers, however, have noticed the flies to be actively feeding in the early morning hours—6.00 a.m.

Although it has been amply proved that the flies are transported by wind from their breeding places to the feeding area, they attack cattle most severely in sheltered areas. The stock most heavily attacked are the animals grazing in pastures enclosed by tree growth. Animals nearby but in open fields exposed to the full force of the wind are not molested to the same extent. On only one occasion have flies been observed to enter a barn and severely bite the animals stabled. This barn was found to be unusually well lighted. Dark barns give animals complete protection.

Severity of Attack. The number of flies that congregate on the underside of some animals is so great that when the hand is moved over that part of the body, crushing the gorged flies, it is completely covered with blood. Some animals are bitten so badly that the affected parts appear to be raw. In others the bites produce countless small oedematous swellings on the affected areas and the dry exudate causes the skin to feel rough to touch.

The "bite" of the black fly is not painful at the time it is inflicted. The itching and pain appear some time later. That probably explains why so many flies can gather on one animal. By the time the animal feels the pain and becomes restless, the damage has already been inflicted.

Effect Upon Livestock Activities. Most farmers notice a decided uneasiness in their cattle on the day of the fly outbreak. In many places livestock seek shelter in the farmyard and try to enter the barn. A few farmers report stampeding in cattle and sheared sheep. Dairy farmers report a lowering of milk production by as much as 50 per cent, no doubt caused by restlessness in their stock and by the physiological effect of the black fly "poison" on the cows.

Host Preference. This black fly shows a decided host preference (Table 1). It appears that hogs are not attacked even when kept in a place where they are exposed as much as other animals. Of 799 hogs recorded in the 1944 survey only one, a boar kept separately near a straw pile, died apparently as a result of fly attack. In the very extensive 1946 outbreak only two hogs were killed. Calves on the whole escape even when kept in the pasture with older animals. Their dense hairy covering protects them from heavy feeding. Similarly, unsheared sheep are not unduly bothered. The sheared animals, on the other hand, are greatly molested. Thus on one farm 28 sheep out of a herd of 55 had been sheared when word was sent to farmers over the radio urging them to cease shearing sheep. Of these 28 animals, 25 were badly bitten and showed heavy swelling under the neck. Five of them died. The 27 unsheared animals showed no effect. The highest percentage of affected animals is found in older bulls and cows. This preference for older cattle may be explained on the basis that these have shorter hair and more extensive bare areas than young animals. To date there has been no indication that this species attacks domestic fowl.

Although it has been found that *Simulium arcticum* does not readily attack man, five cases were encountered in the surveys that clearly indicated fly bites and in two of these the actual fly was recovered and identified. In two cases lesions were observed on the wrist accompanied with itching and severe swelling. In another case, a girl who had been working outside during the outbreak had at least three vesicular lesions on the calf of one leg accompanied by swelling, burning sensation and itching. Swelling and pruritus near the site of attack was also true of the other cases. In all the reaction to the bite appeared to be unusually severe resulting in severe swelling and stiffness of the affected part. In the 1946 outbreak a number of similar cases were encountered.

Clinical Symptoms of Attack. In addition to the oedematous lesions at the site of the bite, the most commonly observed symptom in sick animals is a dropsical swelling in the region of the throat, which in cattle later drops into the dewlap (Millar and Rempel (6)). In sheep and horses the swellings appear about the throat, and later are quite noticeable in the subcutaneous tissue of the chest and sternum. Occasionally horses may show great swellings under the belly extending from the inguinal region forward to the front legs. However, in the 1944 outbreak swellings were noted in only about 3.4 per cent of the animals exposed to black fly attack (Table 1). The highest percentage, 10 per cent, occurred in horses. Swellings were noted in 6.5 per cent of the cows, 4 per cent of the bulls, 3.6 per cent of the sheep, but in less than 1 per cent of the yearling cattle and calves; none was present in hogs. Thus it appears that there is a large proportion of mature animals which do not react in the same way to the fly attack. Some of these apparently normal animals were just as heavily bitten as many of those that were sick or which died as a result of black fly feeding.

Animals that are severely attacked breathe more heavily and rapidly than normal. In late stages of fatal cases there is jerky breathing accompanied by marked shivering. Finally the animal drops to the ground, gasps for breath and dies without a struggle. Schmidt (8) describes very similar symptoms in animals severely bitten by the golubatz fly, but records in addition temporary or permanent blindness. In the recent outbreaks in Saskatchewan blindness was reported in only two animals. Animals that survive the shock of the attack show rapid improvement.

These periodic losses of livestock in Saskatchewan in the past, now definitely known to be occasioned through black fly attacks, have called forth much speculation as to the actual cause of the deaths. Theories that have been advanced are as follows: tick paralysis, plant poisoning, a disease organism, mechanical suffocation caused by inhaling black flies, toxemia and anaphylaxis.

The suddenness and seasonal incidence of the deaths and the widespread nature of the attacks definitely rule out tick paralysis. For the same reason food poisoning cannot be a factor. Moreover, the above theories fail to take into consideration the presence of an unusual number of black flies. Further, the epidemiology of the fatalities during the three outbreaks precludes a contagious disease, and the suddenness of the appearance of the symptoms following the black fly attack eliminates an insect-

borne disease. Mechanical suffocation occasioned through the inhalation of countless numbers of flies with a consequent blocking of the air passages, a theory widely held by laymen, is not a factor. Post-mortem examinations made during the 1944 outbreak (6) failed to disclose any flies in the lungs and air passages. That fatalities resulting from black fly attack are not a clear case of anaphylaxis is indicated by the deaths of a number of lambs, and calves, which could not conceivably have been sensitized. The rareness of illness and death among calves is to be attributed to the mildness of attacks to which they are exposed. The dense hairy covering affords them ample protection against black flies. It must further be emphasized that animals appear to develop an immunity with subsequent attacks, as was also found by Lohmann (4). The serious effects in animals observed in the Saskatchewan black fly outbreaks appear to be the result of an increase in the permeability of the capillaries with a consequent great loss of fluid from the circulatory system into the tissue spaces and body cavities. Post-mortem examinations (Millar and Rempel (6)) reveal that the body cavities, internal organs and tissues have considerable to severe imbibition of a clear serous fluid and show evidence of internal haemorrhages. This is interpreted as a case of shock (as defined by Moon (7)) which is due to a direct toxic action without previous sensitization.

CONTROL

In the control of black flies two main lines of attack are conceivable. The first would involve the destruction of the immature stages of the fly while the second would be directed mainly toward protection of livestock.

The use of miscible oils or larvicides such as DDT in the Saskatchewan River is at present impractical as a control. For the area in question this would involve treatment of a large river for a distance of more than 100 miles. Unless and until further research makes this form of control feasible, reliance will have to be placed on the second line of attack.

Judging from the three recent outbreaks, the chief danger period to livestock is during the initial attack which normally comes without warning. Such attack may come any time between May 25 and June 15. Although flies may be present during the greater part of the remainder of the season they are not likely then to cause fatalities. Livestock fatalities can therefore be prevented by protecting animals from attack during this period.

Several methods have proved highly effective in protecting animals from black fly attack during the recent outbreaks. Keeping valuable stock, especially bulls and milk cows, in dark stables during clear warm days gave complete protection. Farmers in areas most subject to attack by this black fly would therefore be well advised to stable herd sires at least during the greatest danger periods. If feasible, valuable cows should also be stabled during that period. Smudges gave considerable freedom from flies to animals running free in pastures and should be provided and maintained throughout the entire fly period. Repellents in the form of various mineral oils or greases protected the animals treated but the oils had to be applied daily.

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THE NEW HELMINTHOSPORIUM BLIGHT OF OATS FOUND IN ONTARIO[1]

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[Received for publication August 18, 1947]

Helminthosporium victoriae Meehan & Murphy, causes a root rot and leaf blight of certain oat varieties. The disease was first observed at Ames, Iowa, in 1944[4]. During 1946 its occurrence was widespread in the United States and varying degrees of damage to the oat crop were attributed to it. In June 1947 the disease was discovered in the plots of the Cereal Division, Central Experimental Farm, Ottawa. Later it was found in several districts in Ontario.[5]

The new *Helminthosporium* blight attacks the oat varieties and selections that have Victoria as a parent and possess its resistance to crown rust (*Puccinia coronata*). Infected plants were found to occur singly or in small groups scattered among normal plants. In the infected plants the base of the culm and adjoining roots are necrotic accompanied by striping and reddening of the lower leaves, which progresses to the upper ones. Although similar reddening and striping of the leaves may be due to other causes, it is a useful symptom in picking out diseased plants where the blight is present. Towards maturity the disease is readily identified by the basal foot and root rot, the translucent browning of the lower internodes of the culm and the black spore masses on the lower nodes. Such culms are loosely attached to the soil and may fall over. In addition, considerable crinkling or breaking of the culms may be noted. The organism is both soil and seed borne.

In Ontario, *Helminthosporium* blight was found on the two new Canadian oat varieties, Beacon and Garry, as well as on Vicland. It was present also on hybrid material wherein Victoria was a parent. Other varieties appeared resistant. The organism was isolated and identified as *H. victoriae* from the following areas: Ottawa, Fournier, Kemptville, Guelph, Harrow, Blenheim, Chatham, Wallaceburg and Toronto. In many fields only a trace of the disease occurred. In others, as many as three to five per cent of the plants were infected. In fields of Beacon where the seed had not been treated up to seventy-five per cent of the plants were severely diseased, whereas in nearby fields grown from treated seed only a trace of infection was found.

It appears that if varieties of oats involving Victoria in their parentage such as Beacon, Garry and Vicland are to be grown successfully in Ontario, it will be necessary to treat the seed with an organic mercury fungicide. In the United States in 1946 ordinary seed treatment with Ceresan was recommended. There was evidence to show that better control of the disease was obtained where seed had been treated at least two weeks before planting.

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[5] Since this manuscript was submitted for publication, this disease has been found in Quebec, New Brunswick and Manitoba.

It should not be concluded that the oat crop as a whole will be damaged greatly by this new disease. Information on the disease is still very limited. Under a more normal season than that of 1947 it is impossible to say whether the disease will become serious or not. In the meantime, it is known that seed treatment helps to protect the seedlings of susceptible varieties from becoming infected by *H. victoriae*.

BOOK REVIEW

VEGETABLE GROWING, by J. S. Shoemaker. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Limited. 506 pages. illus. 1947. $4.50.

It is a pleasure to review this book written by a prominent Canadian horticulturist. His experience as a teacher and research worker, and his knowledge of the literature, have given him an excellent background for such a book. It is written in a very readable and concise style.

The inclusion of a chapter on Vegetable Seed Production is an excellent idea. Often this important phase of the vegetable industry, which incidently is now becoming well established in Canada, has been neglected or touched on lightly. The author deals with the various kinds of vegetable seeds; methods of growing; standards of purity; harvesting, cleaning, etc. The crops are dealt with in groups, according to the method of pollination.

With the exception of another chapter on Insect and Disease Control, the remaining chapters are devoted to the growing of the various kinds of vegetables, sensibly grouped by crops (*e.g.*, root crops, bulb crops, vine crops, etc.).

Soils, fertilizers, storage, etc., are dealt with as they affect each particular crop, thereby making the section dealing with each crop complete and avoiding reference to special chapters for such information.

The reviewer feels this book would be more complete if: (a) There were more discussion and some recommendations on crop rotations. The increasing need for soil conservation, maintaining humus and the scarcity of manure are important factors in vegetable growing. (b) There were more references to the literature in the text and a list of references at the end of each chapter, instead of a list at the end of the book.

This book will be of great value to teachers and students and a useful reference to all those interested in vegetable growing.

WM. FERGUSON

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